

# Pondering Breakthrough Propulsion and Inertial Frame Physics

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ADVANCED SPACE PROPULSION WORKSHOP

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# Introduction

- **Ambition** – *Timely* interstellar missions
- **Challenge**
  - Rockets constrained by propellant limits
  - Sails limited by externally delivered momentum

- **Approaches**

Improve *Technology*

Rockets, Sails,  
& Beamed Energy

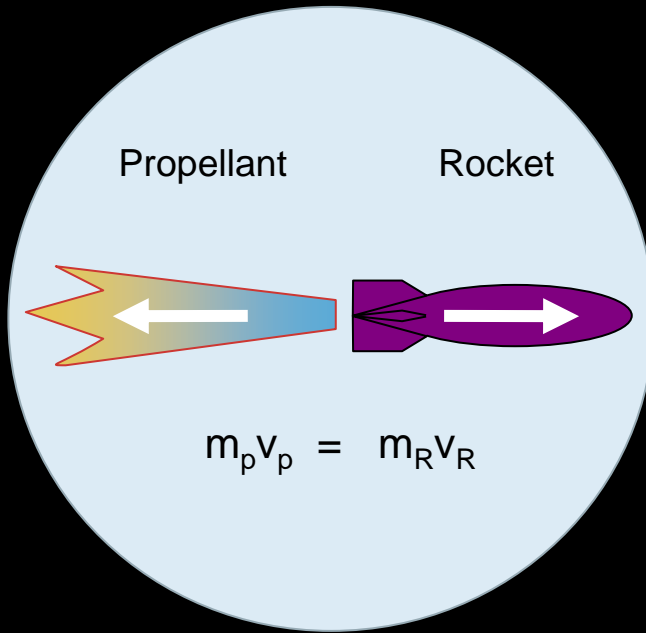
Advance *Physics*

Space Drives & FTL

This Presentation:  
*Space Drives*

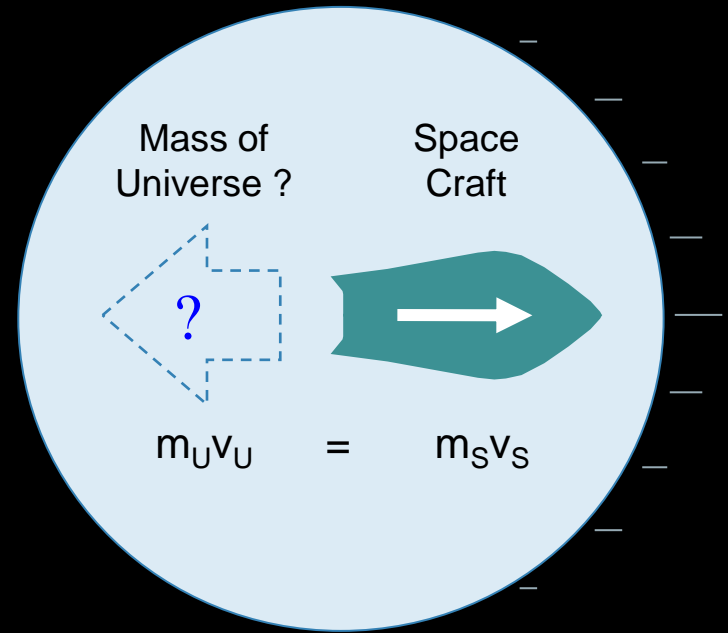


# Rockets



$$E(n, \Delta v) = \frac{1}{2} m (v_{\text{ex}})^2 \left( e^{\left( \frac{n \Delta v}{v_{\text{ex}}} \right)} - 1 \right)$$

# Space Drives



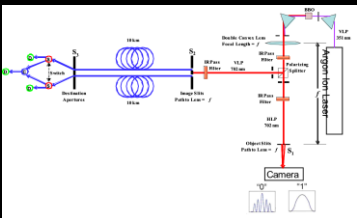
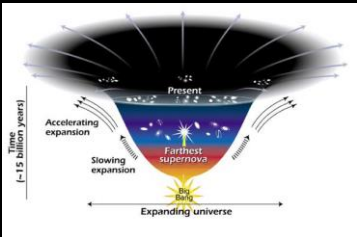
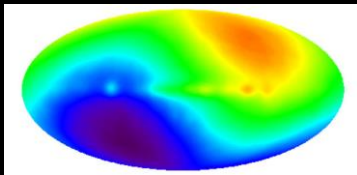
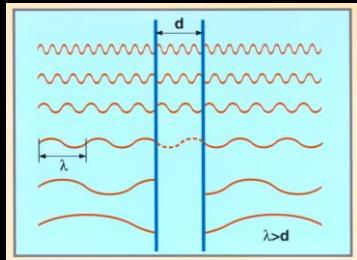
$$E(n, \Delta v) = \frac{1}{2} m n (\Delta v)^2$$



# How to Start?

## Contrast Now to Wow

### Rigorous Foundations



What are the  
unsolved  
questions  
?

Their intersection  
reveals the  
“Important Problems”

What are  
the critical  
issues and  
unknowns  
?

### Goal-Driven Visions



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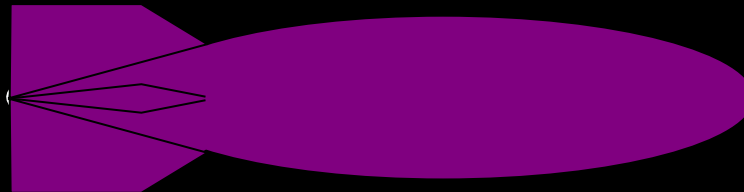


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# ***Rocket Propulsion & Momentum Conservation***



◀ Reaction Mass

Rocket ▶▶

# *Inertial Reference Frames*

- Property of spacetime where *accelerated* motion of matter is detectable – the reference frame for:

$$F = ma$$

- Note that this has terms for *mass*, *space*, and *time*, suggesting that inertia is a *relation* between mass **AND** spacetime, not just a property of mass.
- So ubiquitous it's easy to take for granted – and hard to contemplate.
- Given one inertial frame, there are an infinite number of inertial frames, each moving uniformly to the others (“*Lorentz Invariance*”).



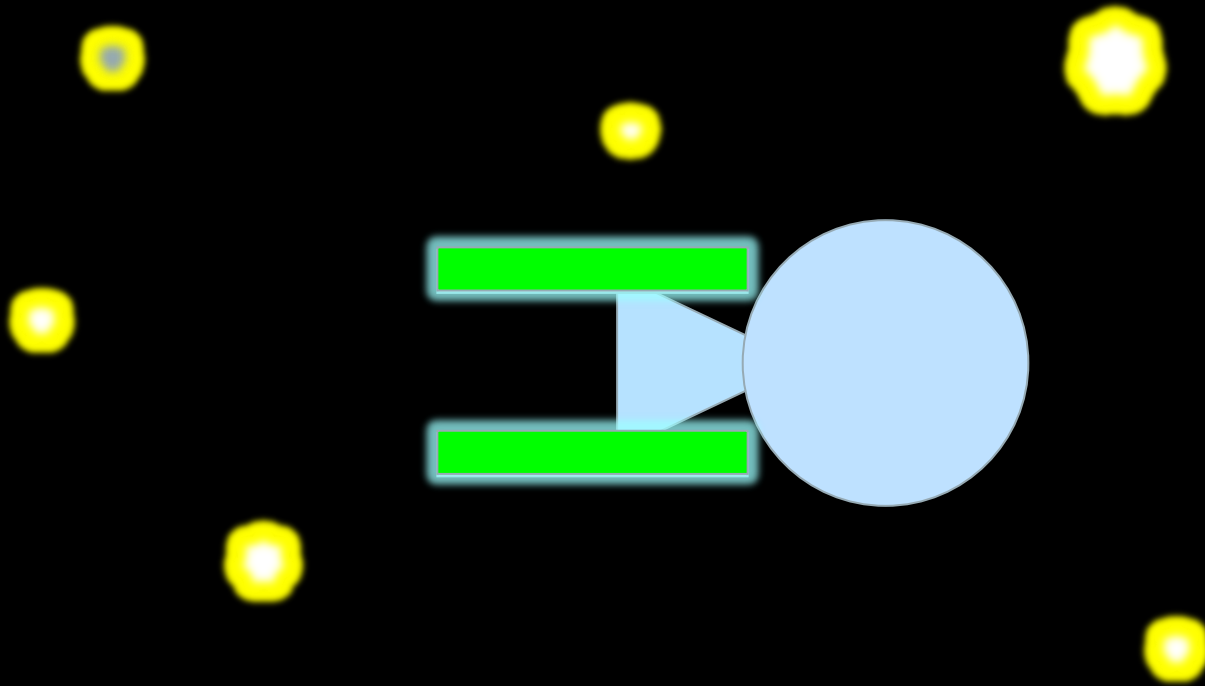
# *Undiscovered Physics*

- **Inertial frame origins & properties still not understood**
  - Reaction with all the matter in universe (Mach's Principle)?
  - Intrinsic property of space regardless of surrounding matter?
- **Geometric Spacetime theories (Einstein/Riemann) are not able to describe momentum conservation for:**
  - Wormhole transport
  - Warp drives
  - Frame dragging propulsion (R. Forward, 63)
- **Inertial frames assumed ad hoc, rather than a focus of inquiry unto themselves.**



# *Cartoon of Desired Operation (Type 1)*

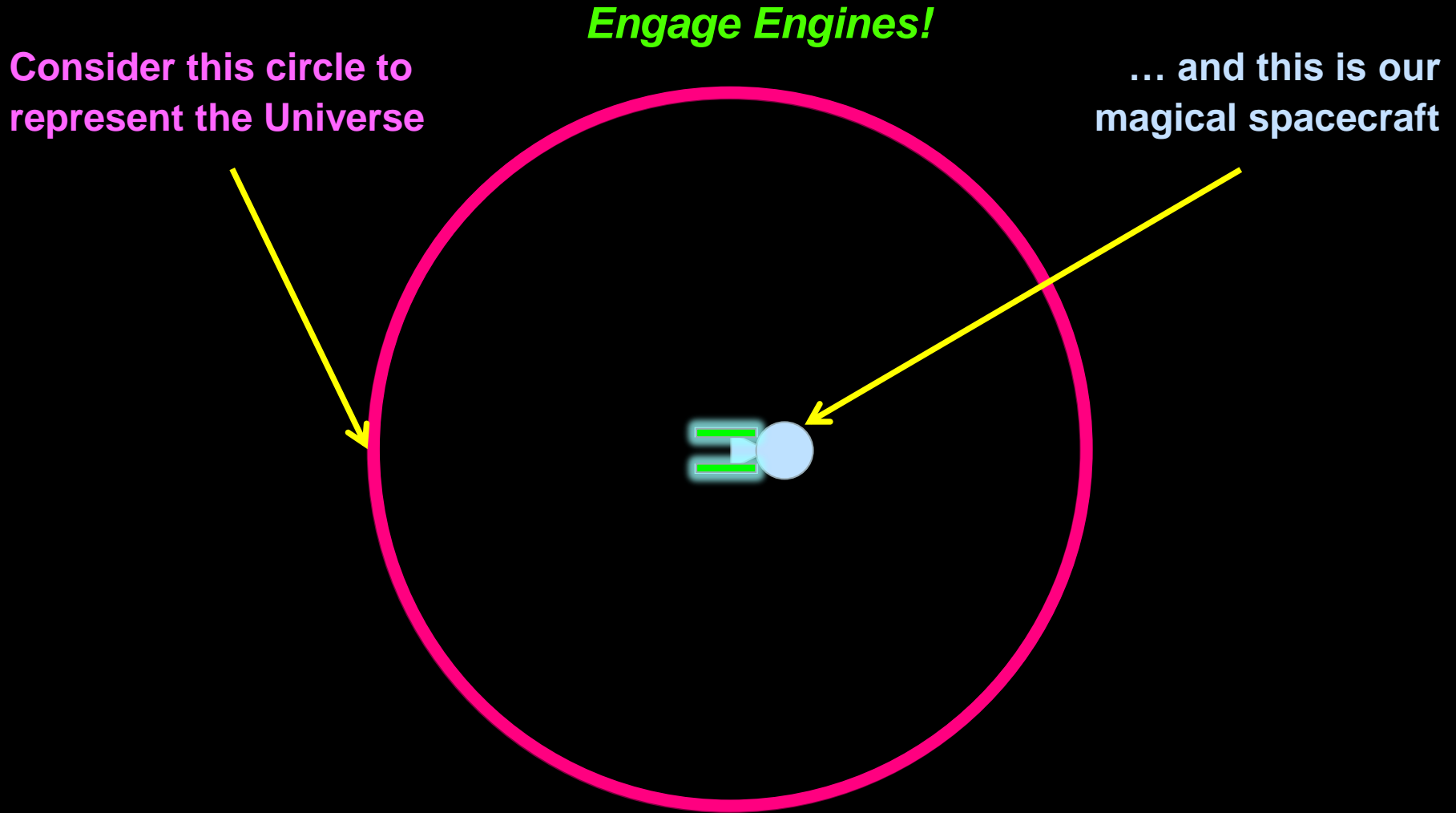
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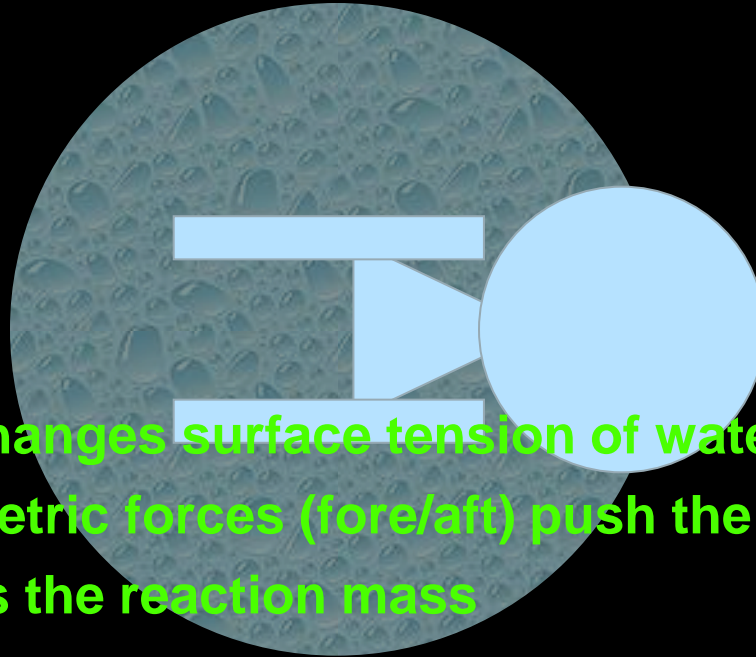
# ***Extend Premise to All Mass of the Universe***

Disclaimer: Only intended to illustrate the concept



# *Cartoon of Desired Operation (Type 2)*

## *Analogy of the "Soap Boat"*



- Soap changes surface tension of water behind craft
- Asymmetric forces (fore/aft) push the craft
- Water is the reaction mass
- Soap is analogous to a local & asymmetric change of spacetime (perhaps;  $G$ ,  $\Phi$ ,  $h$ ,  $c$ , *Quantum Vacuum*, other?)
- Water is analogous to spacetime (reaction mass?)

Disclaimer: Only intended to illustrate the concept

# Mass-Energy Density of Space ?

## In space, of space

- $10^{-26} \text{ kg/m}^3 \approx \text{Total Inferred Mass/Volume}$
- $10^{+25} \text{ kg/m}^3 \approx \text{Analogy to Young's Modulus}$

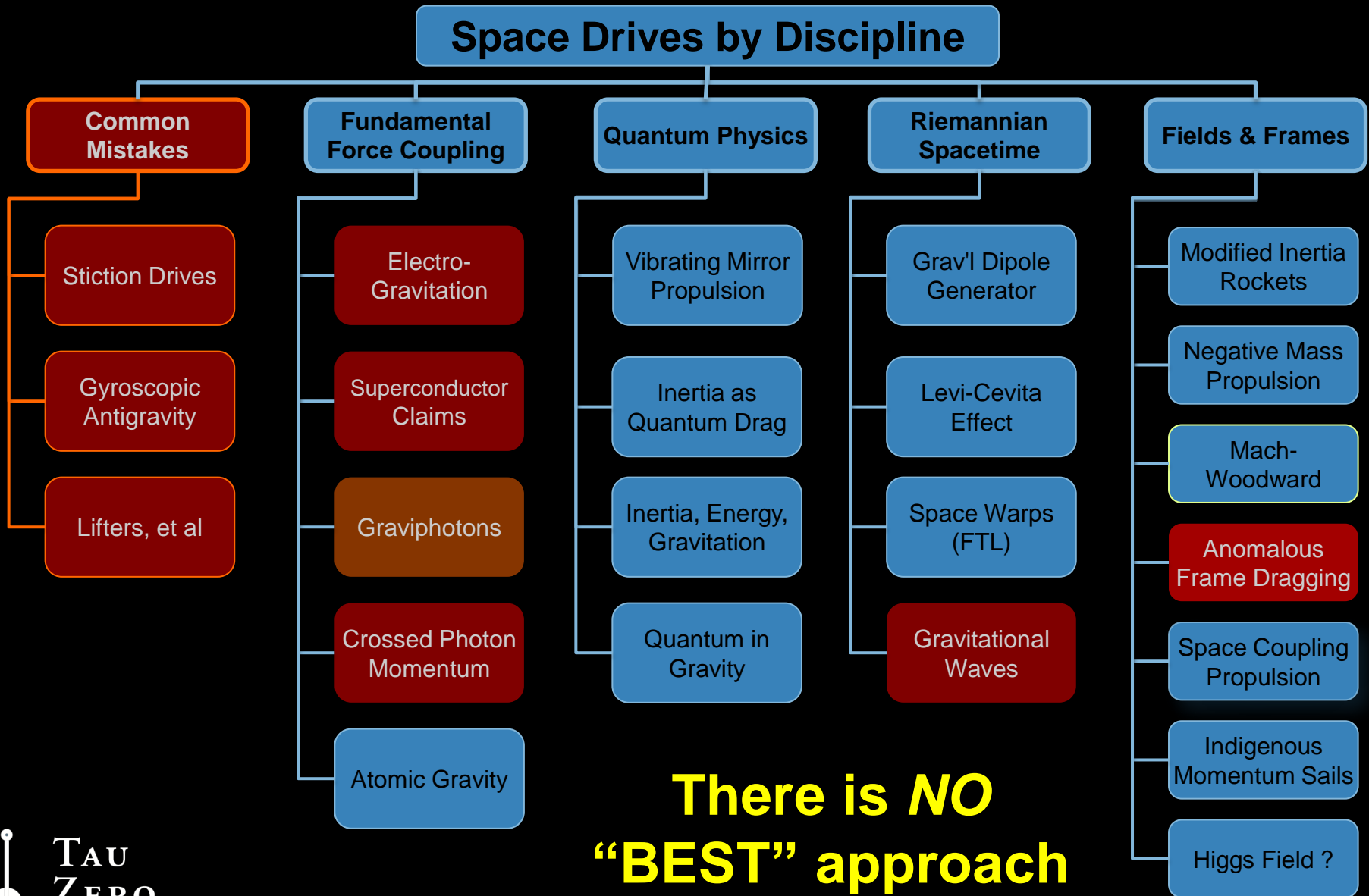
$$Y_{\text{Spacetime}} = \frac{\text{stress energy}}{\text{strain (curvature)}} = \frac{[T^{\mu\nu}]}{\left[R^{\mu\nu} - \frac{1}{2}g^{\mu\nu}R - \Lambda^{\mu\nu}\right]} = \frac{c^4}{8\pi G} = 4.8 \times 10^{42} \frac{N}{m^2} \Rightarrow 10^{25} \frac{kg}{m^3}$$

## Quantum uncertainty energy (zero point)

- $10^{-26} \text{ kg/m}^3 \approx \text{Inferred from Dark Energy}$
- $10^{+98} \text{ kg/m}^3 \approx \text{Up to Planck Limit}$



# 'Space Drive' Approaches



# Important Problems

## Unsolved Physics

### Density of Empty Space

### Inertial frame origins & properties

- Treated as ad hoc
- *Newtonian*: (used to define momentum conservation) origins unknown
- *Geometric*: Momentum Conservation not definable for warp drives, wormholes, and frame dragging

### Coupling of gravitation & inertia with other forces – *incl.* Electromagnetism

- Focus on physics of inertial frames
  - Source?
    - Intrinsic
    - Mach's Principle
  - Relation to other forces and energies?
  - Other properties?
- Look for asymmetric effects (like hysteresis)

## Goal-Driven Issues

### Ambiguous Reaction Mass

### Uncertain Conservation of Momentum

### External Net Thrust

- Between craft and space, *not* inside craft
- Asymmetric energy conversion (from stored energy to energy of motion)

# ***Thought Experiments***

Disclaimer: Only intended to illustrate the process

No definitive hypotheses yet posited.

Only a fraction of the variations shown



# *Inertial Frame*

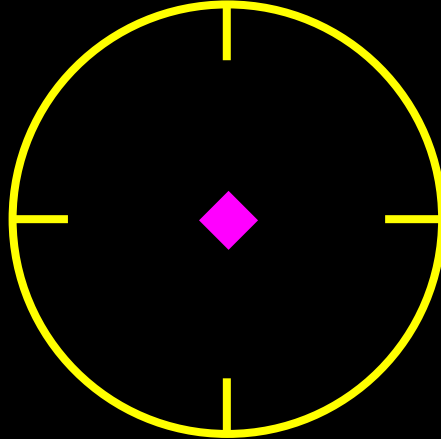
**To contemplate inertial frame *sources*, one must consider:**

- Absence of inertial frame properties
- More than one source of an inertial frame
- Inertial frames of more than one ‘magnitude’



# Starting from Scratch

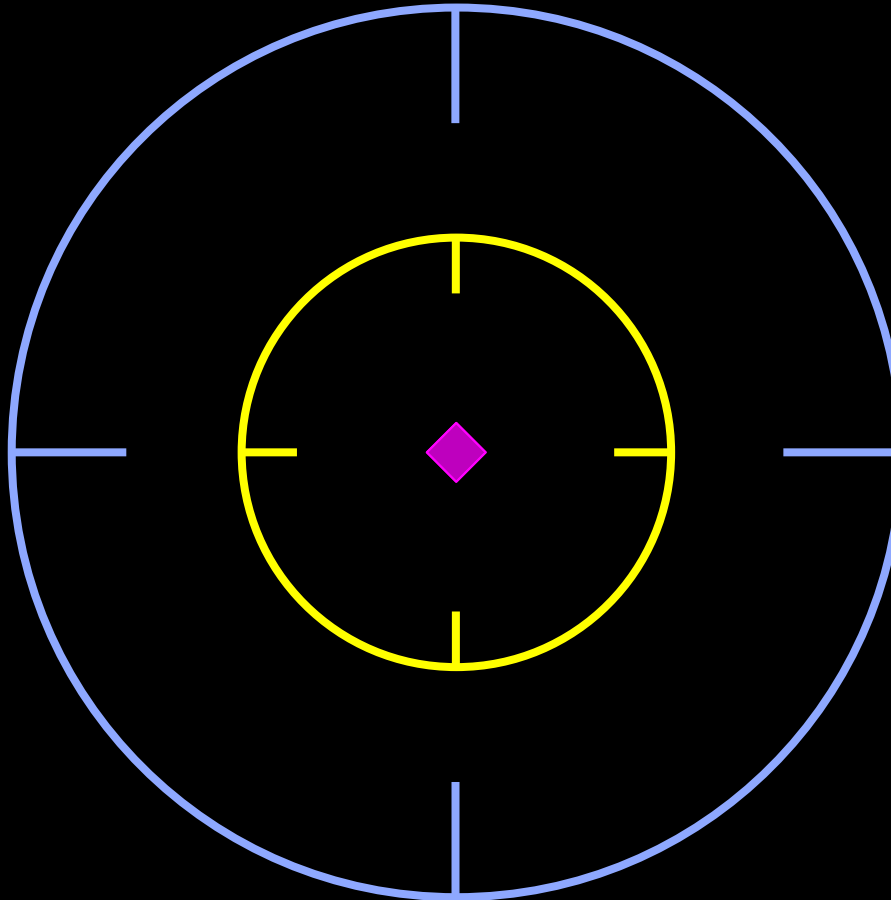
- Start with an empty space that has **NO** inertial frame properties
- Place an **inertial frame** into this void – presumed to have a source, and represented by the yellow reticle.
- Place a **test mass (block)** at rest in this inertial frame
- If we move or rotate the source of the frame (wrt an arbitrary non-physical reference), the mass remains fixed to the frame





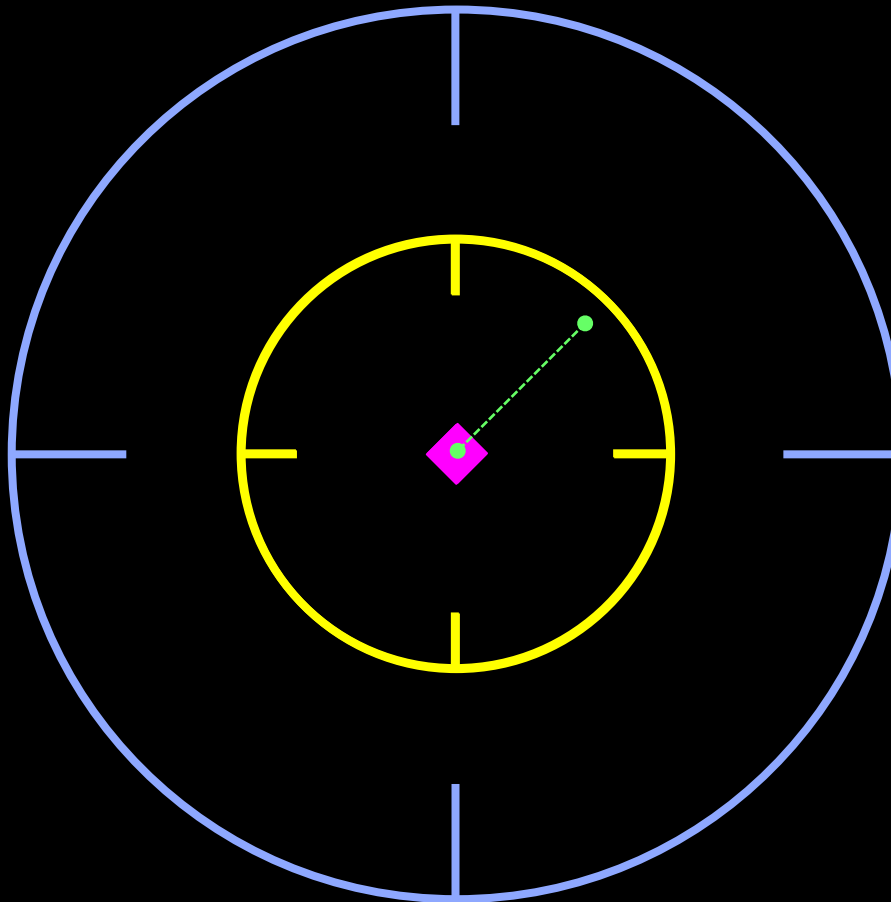
# *Add Another Inertial Frame*

- Now place a second inertial frame (reticle) around the first
- Move the two frames and consider what happens to the test mass.



# *Proportionality of Sources*

- What if only the **Yellow Inertial Frame** existed?
- What if only the **Blue Inertial Frame** existed?
- What if both frames contribute proportionally?



# Continuing the Speculation

- An inertial frame can be considered to be a linear superposition of multiple, *different*, inertial frames
- The POSITION and ORIENTATION of a test particle are 'FIXED' relative to "THE" composite inertial frame
- An analogy to Center of Mass can be used to describe this superposition, but instead of mass, we specify the '*magnitude*' and position of each inertial frame source, "*FI*"

$$FI_0(\vec{x}_{CFI}) = FI_1(\vec{x}_1) + FI_2(\vec{x}_2) + \dots + FI_n(\vec{x}_n)$$

- This requires the use of an arbitrary, fixed, reference frame that is different from any inertial frame (a comprehension subtlety)

# 'Magnitude' of Inertial Frame ?

- If inertial frame properties are now considered to be a *variable*, instead of *ad hoc*, it is necessary to posit what that means
- Consider that the “magnitude” of an inertial frame, “*FI*,” affects the inertia of matter within that frame.
- The greater the magnitude of IF, the greater the inertia of a test particle

$$m_{\text{inertial}}(\vec{x}) \propto FI(\vec{x})$$

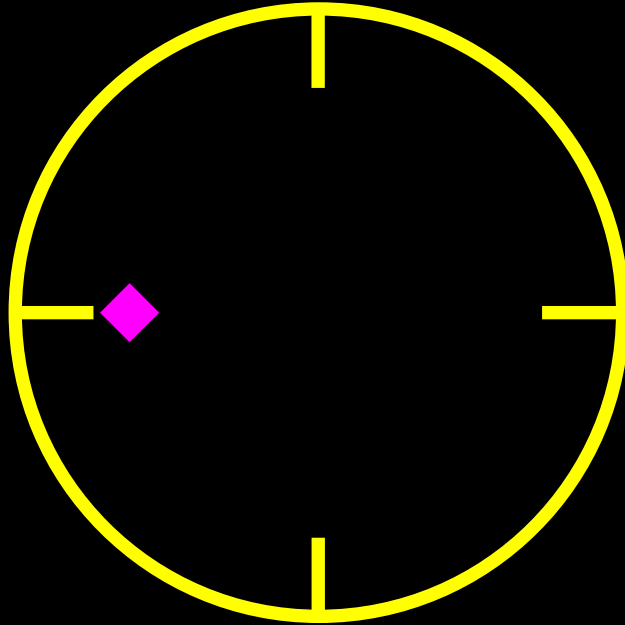
- This is consistent with the thought experiment posited earlier
- *OR...* Can also be interpreted to be a slowing of time

$$\frac{dt_{FI}}{dT_0} \propto \frac{1}{FI}$$

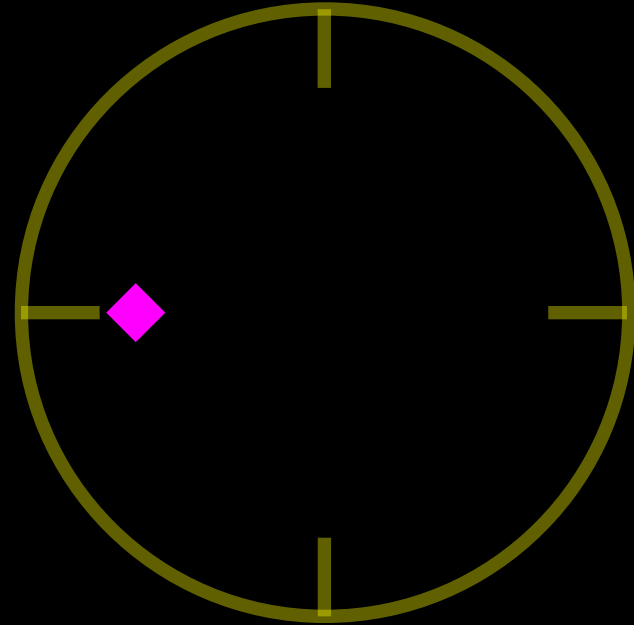


# *Inertial Frame Affects Inertia, Momentum, or Time?*

Greater Magnitude  
Inertial Frame



Lesser Magnitude  
Inertial Frame



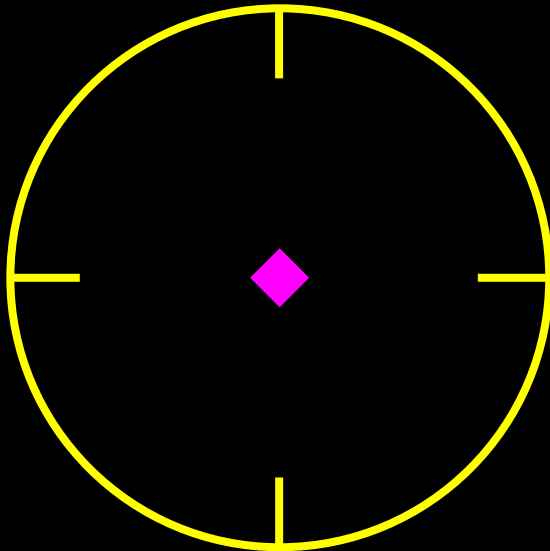
- The same force (momentum) is applied to each test mass
- The resulting acceleration (velocity) is less in the frame of greater magnitude... OR interpreted as a slowing of time



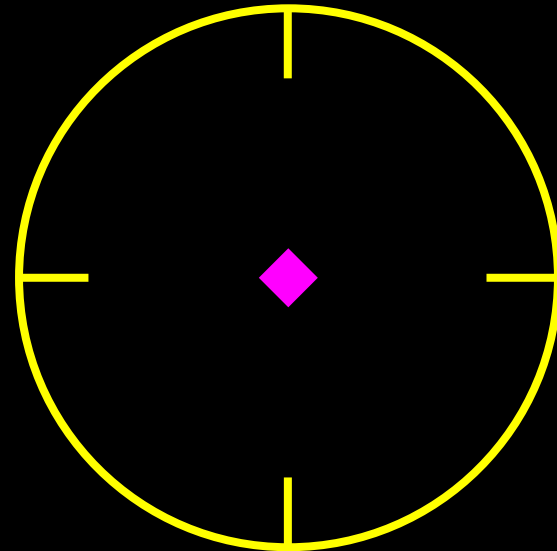
# *Propagation Delay ?*

**What if the inertial frame effect is something that propagates at finite speed?**

If no delay



With finite delay



# Some Inertial Frame Studies

Barbour & Pfister, eds. (1995) *Mach's Principle: From Newton's Bucket to Quantum Gravity*. Boston: Birkhauser

Compilation of different interpretations of Mach's principle and the physics of inertial frames, including transcribed discussions

Assis (1989) On Mach's Principle, *Found of Phys Lett*, **2**, pp.301-318.

Model for inertial frames using analogy to *Weber Force Law*, and where scalar gravitational potential and potential energy play a defining role.

$$F_{u1} = m_1 \left[ a_1 + \omega_u \times (\omega_u \times r_1) - 2\omega_u \times v_1 - \frac{d\omega_u}{dt} \times r_1 - a_u \right]$$

Sciama (1953) On the Origin of Inertia, *M N.Roy.Astron.Soc*, **113**, pp.34-43.

Derives inertia as a gravitational interaction with surrounding mass of universe – not without issues.



# ***Natural Phenomena of Interest***

- **Cosmic Microwave Background**
  - Motion is coincident with mean rest frame of universe
  - Anomalously homogeneous when compared to expected origin as a big-bang side-effect
  - Could it be a side effect of a universal, progenitor inertial frame?
- **Anomalous Gravitation of Galaxies**
  - Stars stay in galaxy despite rotation rates
  - Higher than expected gravitational lensing
  - Predominant hypothesis = “Dark Matter”
  - Could the effect be due to a non-uniform inertial frame?





# ***NEXT: Electromagnetism***

- **Known**

- Light bends near gravitating body
- Light red-shifts departing a gravitating body
- Photons have momentum without mass

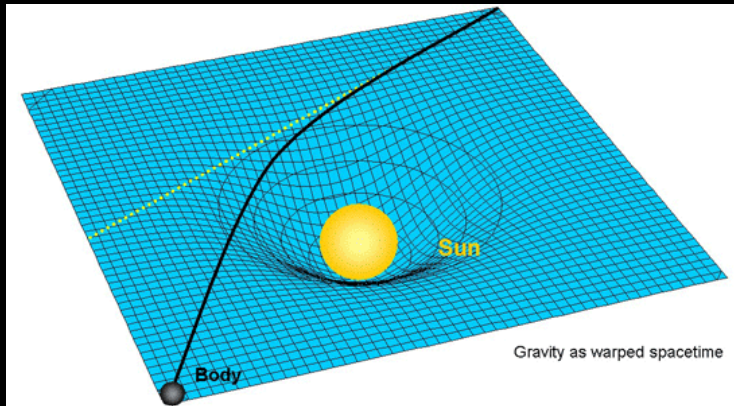
- **Unknown**

- Photon momentum in dielectric media (Two different and incompatible formalisms exist: Abraham–Minkowski controversy)
- Is one a function of the other?
  - Are electromagnetic properties a function of inertia frames or gravitation?
  - Or are inertial or gravitational effects a function of electromagnetism (e.g. *quantum vacuum energy*)?
- Is the propagation speed of gravitation or inertial frame effects the same as light-speed?



# Two Perspectives of Gravitational Lensing

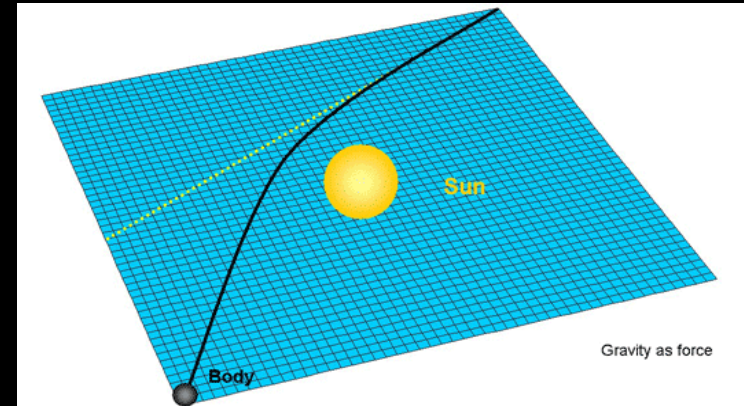
## Warped Spacetime



$$(ds)^2 = \left[1 - 2G \frac{M}{rc^2}\right] (cdt)^2 - \frac{(dr)^2}{\left[1 - 2G \frac{M}{rc^2}\right]} - r^2 (d\theta^2 + \sin^2 \theta (d\phi)^2)$$

$$\theta = 4G \frac{M}{rc^2}$$

## Variable Refraction



$$n = n_0 \left(1 + G \frac{M}{r}\right)^*$$

\* uncorrected

$$\theta = 2G \frac{M}{rc^2}$$



# *Light Bending in Refraction Gradient*



Photo of laser through settled sugar-water

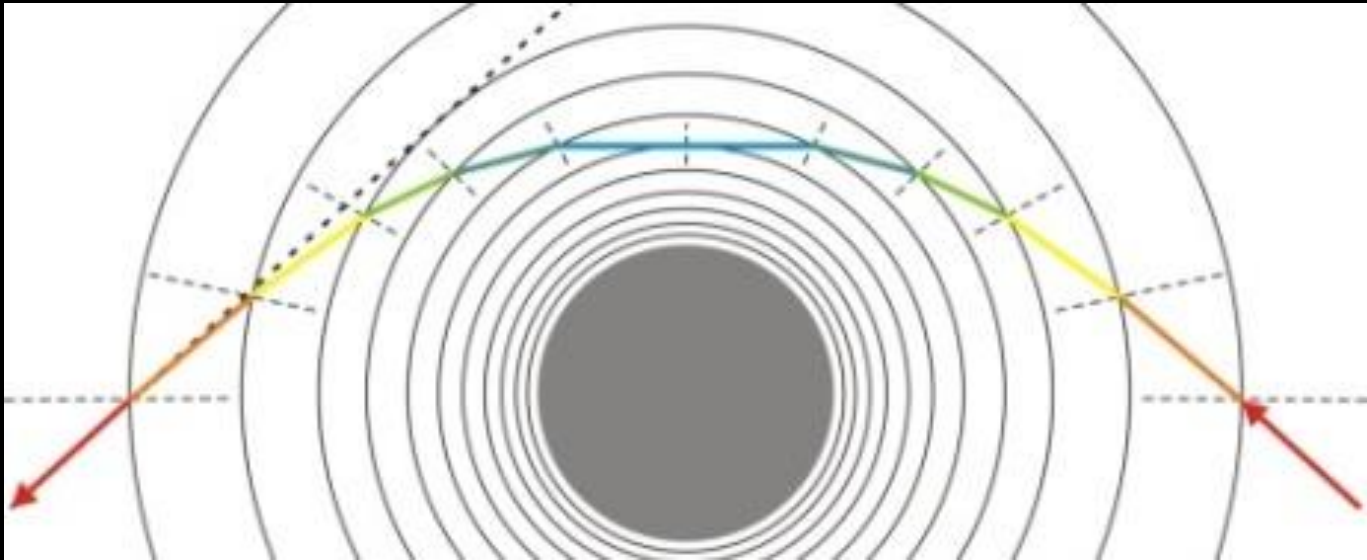
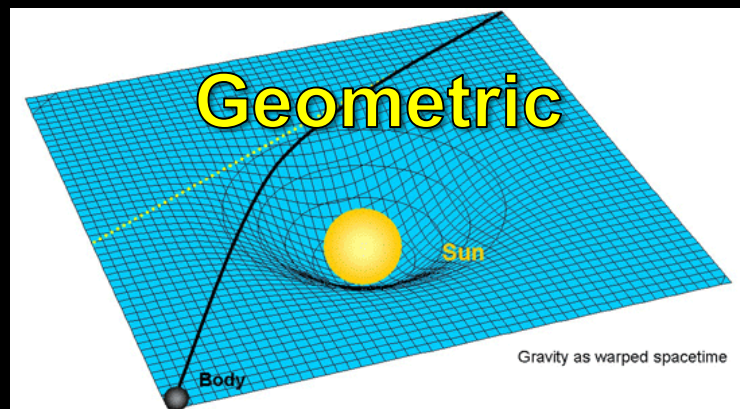


Illustration of bending in concentric indexes



# Two Perspectives of Gravitational Lensing

## Warped Spacetime

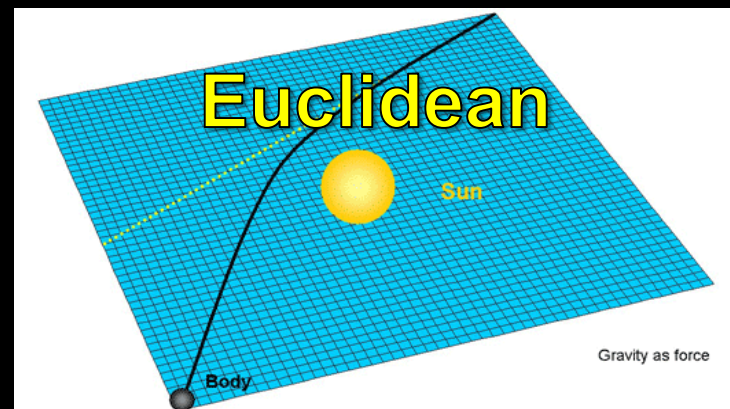


Reference  
Constant

$$d = c t$$

↙ ↘  
vary as function to  
presence of Mass

## Variable Refraction



Reference  
Constant

$$d = c t$$

↙ ↘  
vary as function to  
presence of Mass

i.e. Electromagnetism =  $f(\Phi)$



# Mass-Charge Coupling Refs

Dyson, Eddington, & Davidson. (1920) A Determination of the Deflection of Light by the Sun's Gravitational Field, from Observations Made at the Solar eclipse of May 29, 1919. *Phil. Trans. Roy. Soc. A* **220** 291–333.

Data on light deflection near the Sun that matched Einstein prediction

Epstein & Shapiro (1980) Parameterized Post Newtonian (PPN) deflection of light by the Sun, *Phys. Rev. D* **22**, 2947.

Uses a PPN approximation to calculate the deflection of light in a 'scalar gravity' theory, where the predicted deflection is greater than observed.

de Felice (1971) On the Gravitational Field Acting as an Optical Medium, *General Relativity and Gravitation*, **2**: 347-357..

Uses Euclidean space perspective where space has a index of refraction as a function of scalar gravitational potential (factor of 2 corrected). Several articles assert that this perspective yields identical results to Einstein's geometric version.

Stefanovich (2008) A Hamiltonian approach to quantum gravity, <http://arxiv.org/abs/physics/0612019v10>.

Uses Hamiltonian formalism from quantum mechanics to describe gravitation. Derives light bending as the effect of a gravitating body on light's momentum.



# Considered Perspectives

- Local lightspeed is a function of gravitational scalar potential ( $\Phi$ )
- If the gravitational scalar potential of the combined mass of the universe defines the universal frame, and if lightspeed is defined by that frame, then vacuum lightspeed is related to the mass and radius of the universe

Eddington	$n_r(M, r) = n_0$	$+ n_0 G \frac{M}{r}$
Wilson	$c_r^2(M, r) = c_0^2$	$- G \frac{M}{r}$

Baseline value – defined by magnitude of universal inertial frame?

Effect from local ( $\Phi$ )

$$c_0^2 \approx G \frac{M_u}{R_u}$$



# *In Terms of Other Fundamentals*

Index of refraction and lightspeed are related to the permittivity,  $\epsilon$ , and permeability of space,  $\mu$ .

$$c_{\Phi}^2(M, r) = c_0^2 - G \frac{M}{r} = c_0^2 \left( 1 - G \frac{M}{rc_0^2} \right)$$

$$c^2 = \frac{1}{\epsilon\mu}$$

$$\epsilon_{\Phi}(M, r) \propto \epsilon_0 \left( 1 - G \frac{M}{rc_0^2} \right)$$

$$\mu_{\Phi}(M, r) \propto \mu_0 \left( 1 - G \frac{M}{rc_0^2} \right)$$



# Test With Capacitor Sensors

- **Capacitance affected by:**
  - Vacuum permittivity =  $f(\text{inertial frame})$
  - Local permittivity =  $f(\text{gravitational potential @ } r)$
  - Permittivity of dielectric =  $f(\text{material})$  {2 formalisms}

$$C_{\Phi\text{test}} = \frac{A}{d} (\epsilon_{\Phi} + \epsilon_r) = \frac{A}{d} \left( \left[ \epsilon_0 \left( 1 - G \frac{M}{rc_0^2} \right) \right] + \epsilon_r \right)$$

$$C_{\Phi\text{test}} \propto \epsilon_0 - \epsilon_0 G \frac{M}{rc_0^2} + \epsilon_r$$

function of universal inertial frame?

Material dependant

Effect from local  $\Phi, r$





# Work Plan

## Revise equations of inertial frames w.r.t. surrounding matter...

- Entertain hypothesis that inertial frames are a gravitationally based phenomena [e.g, Assis, Sciama, et al]
- Use retarded potentials to include a finite propagation rate
- Use placeholders for scaling coefficients, instead of assuming 'constants' like  $G$ ,  $h$ , and  $c$ .
- Treat electromagnetism as having a functional dependence on inertial frames –and– the local gravitational scalar potential [e.g, Eddington, Wilson, deFelice, et al]
- Select one of the two formalisms for photon momentum in dielectrics
- Reduce all of the above to predict electrical properties of capacitors at different altitudes ( $\Phi$ ), acceleration ( $g$ ), and wrt motion relative to the mean rest frame of the universe.
- Designs capacitors and detection circuitry... Built, test, learn, iterate



# *If... New Phenomena Detected*

- **Reverse the correlation; attempt to convert *sensing* principles into *effectors***
- **Input electrical energy into effectors, testing if they...**
  - Induce inertial frame gradients (same as gravitational field)?
  - Induce *asymmetric* gradients?
  - Experience reaction forces?
- **Apply those principles to propulsion**

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